Chapter 9: Combustion Area Sources

LESSON GOAL

Demonstrate, through successful completion of the chapter review exercises, a general understanding of the methodologies for calculating emissions from residential wood combustion, residential and land clearing debris burning, agricultural field burning, and wildland fires.

STUDENT OBJECTIVES

When you have mastered the material in this chapter, you should be able to:

1. Explain the method used in the MANE-VU study to estimate emissions from residential wood combustion sources.
2. Explain the method used in the NEI for calculating emissions from residential wood combustion sources.
3. Identify the difference between the MANE-VU method and NEI method for estimating emissions from residential wood combustion sources.
4. Explain the method used in the NEI for estimating emissions from residential open burning.
5. Identify the different types of residential open burning.
6. Identify ways in which the NEI method for estimating emissions from residential open burning can be improved.
7. Explain the method used in the NEI for estimating emissions from land clearing debris burning.
8. Identify ways in which the NEI method for estimating emissions from land clearing debris burning can be improved.

9. Explain the general method for estimating emissions from agricultural field burning.

10. Explain the general method for estimating emissions from wildland fires.

11. Identity some of the efforts underway to improve the methods for estimating emissions from wildland fires.

Chapter 9: Combustion Area Sources

This Chapter covers three types of combustion area sources: residential wood combustion, residential/land clearing debris burning, agricultural field burning, and wildland fires.

9.1 RESIDENTIAL WOOD COMBUSTION

9.1.1 MANE-VU Emissions Inventory

The MANE-VU View Regional Planning Organization conducted a residential wood combustion survey to develop an emissions inventory for the year 2002. The approach of using a survey is the EIIP preferred method for this category. The objective of the MANE-VU project is to prepare a 2002 inventory based on a survey of household equipment usage and wood consumption patterns. The survey method is a stratified random sampling approach. The data collected for each household consists of wood consumption at the equipment level for both real wood and artificial logs, the type of real wood, and the temporal activity to calculate monthly, weekly, and daily emissions.

9.1.1.1 Sampling Frame

The sampling was designed to address major sources of variability in wood consumption activity. These sources of variability include the location and type of housing, the heating demand expressed as heating degree days (HDD), and the availability of wood.

Housing data from the 2000 census was used to stratify the sample by four categories: urban, suburban, rural single family, and other homes. The other homes category includes multi-family units such as apartments, condominiums, and mobile homes. The rural single-family category was stratified into forested versus non-forested areas using USGS-GIS data. Total annual heating degree days were used to further stratify the sample into three zones: low, medium and high.

Table 9-1 is a sample frame shown in a grid. Within each cell the number 61 is the minimum sample size that was determined based on calculations for the precision desired from the survey. The numbers in parentheses represent the number of surveys that were actually collected or completed. Surveys for which the respondents did not categorize correctly were removed from the sample.

Table 9-1. Sample Frame

Geographic Zone	Rural-Forested		Rural Non-Forested		Suburban		Urban	
	Single-Family	**Other**	**Single-Family**	**Other**	**Single-Family**	**Other**	**Single-Family**	**Other**
High HDD	**Cell 1** 61 (173)	**Cell 2** 61 (64)	**Cell 3** 61 (87)	**Cell 4** 61 (66)	**Cell 5** 61 (61)	**Cell 6** 61 (72)	**Cell 7** 61 (69)	**Cell 8** 61 (69)
Low HDD	**Cell 9** 61 (150)	**Cell 10** 61 (62)	**Cell 11** 61 (118)	**Cell 12** 61 (69)	**Cell 13** 61 (76)	**Cell 14** 61 (67)	**Cell 15** 61 (75)	**Cell 16** 61 (62)
Med HDD	**Cell 17** 61 (87)	**Cell 18** 61 (60)	**Cell 19** 61 (91)	**Cell 20** 61 (64)	**Cell 21** 61 (71)	**Cell 22** 61 (60)	**Cell 23** 61 (63)	**Cell 24** 61 (68)

9.1.1.2 Survey Instrument

The survey instrument is a questionnaire developed to gather the activity data on indoor equipment (fireplaces, woodstoves, pellet stoves, furnaces, and boilers), and outdoor equipment (fire pits, barbeques, fireplaces, and chimineas). A pilot survey was conducted to test the questionnaire. Based on the pilot survey, questions were rephrased to clarify the questions in order to collect the information that was needed to characterize the activity. The survey was conducted using computer-assisted telephone interviewing with over 1,900 surveys being completed across all 24 cells.

9.1.1.3 Data Reduction

After completion, the surveys were quality assured to make sure that the data collected made sense. Also, the user fraction (i.e., the fraction of the total household population that burns wood in indoor and outdoor equipment), the annual activity (i.e., cords of wood by equipment and wood types), and temporal data were summarized for each cell. Finally, statistical analyses were conducted to identify significant differences between cells for the user fraction and annual activity.

9.1.1.4 Results and Observations

Table 9-2 is the same as Table 9-1 with the exception that the grid cells have the fraction of indoor wood burning equipment on a percentage basis. In some cases the fractions add up to more than 100% because some houses were using more than one piece of equipment. It should be noted that the rural forested areas within a high heating demand zone has a higher diversity of equipment and more households are using wood burning equipment than the urban areas.

Table 9-2. Sample Frame

Geographic Zone	Rural-Forested		Rural Non-Forested		Suburban		Urban	
	Single-Family	Other	Single-Family	Other	Single-Family	Other	Single-Family	Other
High HDD	**Cell 1** FP=34 WS=67 F/B=21 PS=**4**	**Cell 2** FP=75 WS=75 F/B=0 PS=0	**Cell 3** FP=43 WS=76 F/B=7 PS=0	**Cell 4** FP=33 WS=67 F/B=0 PS=0	**Cell 5** FP=36 WS=64 F/B=**18** PS=0	**Cell 6** FP=0 WS=0 F/B=0 PS=0	**Cell 7** FP=80 WS=30 F/B=0 PS=0	**Cell 8** FP=100 WS=0 F/B=**50** PS=0
Low HDD	**Cell 9** FP=60 WS=65 F/B=5 PS=2	**Cell 10** FP=100 WS=0 F/B=0 PS=0	**Cell 11** FP=61 WS=54 F/B=**4** PS=4	**Cell 12** FP=50 WS=50 F/B=0 PS=0	**Cell 13** FP=70 WS=35 F/B=0 PS=5	**Cell 14** FP=67 WS=0 F/B=0 PS=33	**Cell 15** FP=90 WS=10 F/B=0 PS=0	**Cell 16** FP=100 WS=0 F/B=0 PS=**20**
Med HDD	**Cell 17** FP=55 WS=66 F/B=7 PS=7	**Cell 18** FP=60 WS=60 F/B=0 PS=0	**Cell 19** FP=59 WS=45 F/B=0 PS=9	**Cell 20** FP=100 WS=0 F/B=0 PS=**25**	**Cell 21** FP=81 WS=27 F/B=**8** PS=4	**Cell 22** FP=50 WS=50 F/B=0 PS=0	**Cell 23** FP=100 WS=0 F/B=0 PS=0	**Cell 24** FP=0 WS=0 F/B=0 PS=0

FP = Fireplace; WS = Woodstove; F/B = Furnace/Boiler; PS = Pellet Stove
Totals do not always add to 100 since some respondents use more than one type of equipment. Values in **bold** are derived from responses that were identified as wood consumption outliers (equipment could be mis-categorized by respondent).

Another observation is that rural areas have a higher percentage of stoves and furnaces and boilers than urban areas. Urban and suburban areas have a lower diversity of equipment types and a higher percentage of fireplaces than rural areas. With respect to heating demand, rural areas have a higher percentage of stoves and furnaces in the higher HDD zone, and rural areas have a higher percentage of fireplaces in the lower HDD zone.

For indoor equipment, because of the sample size of the survey, it was hard to find households that burned wood in urban areas. However, the urban sample size was not increased (due to budget constraints and priorities) to obtain a representative sample for three instead of two HDD zones. As a result, emissions were not calculated for each piece of indoor equipment in urban areas. Rather, in order to maintain precision, the equipment and fuel-based survey results were used to estimate average emissions (pound of $PM_{2.5}$ per household per year) and a household-based statistical model was used to estimate emissions for each cell for indoor equipment.

Because there was enough data collected to maintain the sample frame precision, emissions were estimated for outdoor equipment using the survey results. The emissions are the product of the fraction of outdoor equipment users per cell, the annual activity, and the emission factor. This is the first attempt to estimate emissions from outdoor wood burning equipment at the household level and is a tremendous improvement over the NEI, which only includes indoor equipment.

9.1.1.5 Emission Inventory Development

Emissions were estimated for all criteria pollutants and precursors, and several dozen toxic air pollutants. They were estimated at the census track level and summed to the county, state and region. Emissions were temporally allocated to support modeling using profiles that were developed from the survey.

9.1.1.6 Lessons Learned

The survey instrument for regional surveys should be tailored to suit the usage patterns on rural and suburban and urban areas. It is difficult to find wood burners in the urban areas, and the sample size may need to be increased to locate these sources. For indoor equipment, to keep resources manageable, the use of statistically derived emissions based model (household level) instead of an equipment specific method should be considered. The concern with this MANE-VU approach, however, is that it aggregates emissions for different types of wood burning equipment, which should be disaggregated in order to conduct a control strategy analysis.

9.1.1.7 Documentation

Documentation for the MANE-VU project can be obtained at www.manevu.org/pubs/index.asp. This contains the work plan, including the equations for calculating the sampling precision.

9.1.2 NEI

The NEI categorizes fireplaces into four SCCs and woodstoves into three SCCs as shown in Table 9-3. A description of the equipment associated with each SCC is also included in Table 9-3.

Table 9-3. NEI SCCs for Residential Wood Combustion

SCC	Combustion Source
	FIREPLACES
2105008001	Without Inserts
2104008002	With Inserts; Non-EPA Certified
2104008003	With Inserts; Non-Catalytic, EPA Certified
2104008004	With Inserts; Catalytic, EPA Certified
	WOODSTOVES
2104008010	Non-EPA Certified

2104008030	Catalytic, EPA Certified
2104008050	Non-Catalytic, EPA Certified

The pollutants included in the NEI for residential wood combustion include PM_{10} primary, $PM_{2.5}$ primary, NO_X, CO, SO_X, and HAPs. The emission factors that are used for residential wood combustion represent primary emissions. There is no breakout of the filterable and condensable portions of the emission factor for this category.

9.1.2.1 Emission Factors

The emission factors used in the NEI for fireplaces without inserts (pounds pollutant per ton of dry wood) are obtained from AP-42 except for PM and CO which are obtained from Houck, J.E. et al, *Review of Wood Heater and Fireplace Emission Factors*. The $PM_{2.5}$ emission factor is assumed to be the same as the PM_{10} primary emission factor. The emission factors for all pollutants from woodstoves and fireplaces with inserts are obtained from AP-42.

9.1.2.2 Emission Estimation Methodology

The NEI developed separate national wood consumption estimates and, therefore emission estimates, for fireplaces with inserts, fireplaces without inserts, and woodstoves to account for the different emission factors and different usage patterns. The methodology is different for fireplaces without inserts than it is for fireplaces with inserts and woodstoves. As such, these are discussed separately in the following sections.

9.1.2.2.1 Fireplaces without Inserts

The first step in estimating emissions from fireplaces without inserts is to determine the number of homes with fireplaces in the United States. These data can be obtained from the US Department of Census (DOC). These data need to be adjusted to account for the fact that some homes have more than one fireplace (multiply by 1.17) and for the fact that not every home burns wood (74% burn wood, 26% burn gas).

After making the adjustments to account for multiple fireplaces and those that burn wood, the number of fireplaces not being used (42% not used) and the number of fireplaces with inserts are subtracted. Fireplaces with inserts are treated in the same manner as woodstoves and are discussed in section 9.1.2.2.2.

Based on DOC data the NEI separated fireplaces without inserts into 2 categories; those used for heating and those used for aesthetics. The amount of wood burned in each device is determined by assuming wood consumption rates of 0.656 cords burned /unit/year for fireplaces used for heating and 0.069 cords/unit/year for fireplaces used for aesthetics. In 1997, EPA estimated that 2.94 million cords of wood were burned in the former and 0.483 million cords of wood were burned in the latter.

Once the national wood consumption for fireplaces without inserts is calculated it is necessary to allocate it to 1 of 5 climate zones based on temperature, and demographics/population (i.e., the number of single-family home). Within each climate zone, wood consumption is allocated to individual counties.

Table 9-4 shows the climate zones defined by the ranges of heating degree day and cooling degree day values as well as the amount of national consumption that is allocated to each zone.

Table 9-4. Climate Zones

Climate Zone	Percent of Wood Consumed
1 (>7000 HDD)	36
2 (5500-7000 HDD)	19
3 (4000-5499 HDD)	21
4 (<4000 HDD and <2000 CDD)	15
5 (<4000 HDD and >2000 CDD)	9

The census data classifies counties as either urban or rural. A county is classified as urban if 50 percent of the county's population is located in cities and towns and it is classified as rural if less than 50 percent of the population is located in cities and towns. The total wood consumption for all the urban counties are summed for each climate zone, and the same is done for the rural counties. The data is adjusted if the percentage proportion between urban and rural areas does not match the percentage in the number of units that are reported in the 2001 census. This data is shown in Table 9-5. For example, if the total wood consumption for woodstoves in climate zone 1 is 60 percent for rural and 40 percent for urban, then each urban and rural county within zone 1 receives a percent increase or decrease in cordwood consumption to obtain the correct percent split to reach the 65 percent rural and 35 percent urban split for zone 1.

Table 9-5. Urban/Rural Apportionment Data

Type	Rural	Urban
Woodstoves	65%	35%
Fireplaces with Inserts	43%	57%
Fireplaces without Inserts	27%	73%

Finally, AP-42 factors are used to determine county emissions from fireplaces without inserts.

9.1.2.2.2 Fireplaces with Inserts and Woodstoves

The first step in estimating emissions from fireplaces with inserts and woodstoves is to determine the number of woodstoves and inserts in the United States. These data are obtained from the DOC and are adjusted for the fact that some homes have more than one stove. Also, units used for main heating purposes are considered different from units that are used for other heating purposes (e.g., aesthetic).

The total cords of wood consumed by the residential section for 1997 are obtained from the Energy Information Administration (EIA). Since this value does not include consumption for aesthetic purposes, it is necessary to subtract the cords of wood used in fireplaces for aesthetic purposes.

Using the same approach that was used for fireplaces without inserts, the national wood consumption for fireplaces with inserts and for woodstoves is allocated to 1 of 5 climate zones (see Table 9-4). Within each climate zone, the wood consumption is allocated to the individual counties using the relative percent of detached single family homes in the county to the total number of detached single family homes in the entire climate zone.

After allocating to the climate zones, the wood consumption in each zone is summed and compared the urban and rural split. The total is adjusted until the desired split is achieved. For woodstoves, the split is 69 percent rural and 31 percent urban. For inserts, the split is 50/50. For example, if the total wood consumption for woodstoves in climate zone 1 was 60 percent for rural 40 percent fir urban, then each urban and rural county with that zone would receive a percent increase or decrease in cordwood consumption to obtain the correct percent split to reach the 69 percent rural and 31 percent urban split.

Wood consumption for woodstoves and fireplaces with inserts are allocated to one of the three SCCs as shown in Table 9-6. Fireplaces without inserts are recorded on one SCC, so there is no need to allocate to SCCs.

Table 9-6. Apportionment for Woodstoves and Fireplaces with Inserts

Type of Device	Percent of Total Wood Consumption
Non-Certified	92
Certified Non-Catalytic	5.7
Certified Catalytic	2.3

Once the amount of wood consumed per residential wood combustion type is obtained, AP-42 emission factors are used to calculate emission estimates.

9.1.2.3 Seasonal Adjustment

When the NEI method was developed the seasonal activity was allocated by climate zone. The seasonal throughput percentages assigned to each climate zone are listed in Table 9-7. Zone five is the warmest zone, so all the activity was placed into the winter category. Summer has no activity with the NEI default method, and the activity is distributed across the seasons for zones two, three and four.

Table 9-7. Apportionment for Woodstoves and Fireplaces with Inserts

Climate Zone	Winter	Spring	Summer	Fall
5	100	0	0	0
4	70	15	0	15
3	50	25	0	25
2	40	30	0	30
1	33.33	33.33	0	33.33

9.1.2.4 Improving the NEI

One approach to improving on the NEI method is to conduct a local survey, or allocating emissions within the seasons. It is preferable to use local data and the preferred collection method is to do a local or statewide survey. The EIIP provides an alternative method that uses the bureau census data and the EIA data method. Any assumptions other than 100% for rule effectiveness and rule penetration should be incorporated into the emissions estimation methodology since the NEI method does not account for the effect of state and local rules. Finally, the residential wood combustion section of the EIIP series (Chapter 2 of Volume III) contains information on conducting a survey.

9.1.3 Comparison of the MANE-VU and NEI

The MANE-VU inventory is a bottom-up methodology and the NEI is top down. MANE-VU provides better estimates by geographic area and census. It also accounts for differences in housing type (single versus multi-family homes). MANE-VU provides better estimates of usage patterns based on heating demand, and it includes outdoor equipment not included in the NEI estimates. It also provides some temporal data that can be used to allocate emissions.

9.2 Residential/Land Clearing Debris Burning

9.2.1 Residential Open Burning

Residential open burning includes household waste burning and yard waste burning, which includes brush waste and leaf waste.

9.2.1.1 NEI

Table 9-8 lists the SCCs and the pollutants for residential open burning that are included in the NEI.

Table 9-8. Residential Opening Buring SCCs and Pollutants

Category	SCCs	Pollutants
Residential Municipal Solid Waste Burning	2610030000	PM_{10}, $PM_{2.5}$, CO, NO_x, VOC, SO_2, 32 HAPs
Residential Leaf Burning	2610000100	PM_{10}, $PM_{2.5}$, CO, VOC, 6 HAPs
Residential Brush Burning	2610004000	PM_{10}, $PM_{2.5}$, CO, VOC, 6 HAPs

The first step in developing activity data for residential municipal solid waste is to estimate the rural population by county by applying percentages of rural and urban population from the census data. The second step is to multiply the rural population by a per capita household waste factor of 3.37 pounds per person per day. Once the total waste generated is estimated, the amount of waste burned is estimated by assuming that 28% of the household waste generated is burned. The final step is to account for burning bans. Ideally this is done by knowing exactly which areas have instituted a burning ban and the time period over which the ban applies. However, the NEI assumes that if a county has an urban population that exceeds 80% of the total population the amount of waste burned is zero.

The activity data for yard waste is estimated in a similar manner to household waste using a per capita waste factor for yard waste generation of 0.54 pounds per person per day. However, since different types of yard waste materials have different emission factors it is necessary to estimate the percentage of total yard waste that corresponds to leaf, brush, and grass waste. The NEI assumed that 25% was leaf waste, 25% was brush waste, and 50% was grass waste. The amount of waste burned is estimated by assuming that 28% of the total leaf and brush waste is burned and that 0% of the grass waste is burned. One additional adjustment is made to the amount of yard waste burned to try to account for the variation in vegetation among the counties. This is done by using an estimate of the percent of the forested acres per county that was obtained from the biogenic emissions land cover database from the Biogenic Emission Inventory System (BEIS) as shown in Table 9-9. For example, if the BEIS data indicates that a county has less than 10% forested acres, the NEI assumes that there is no yard waste generated.

Table 9-9. Vegetation Adjustment Values

Percent Forested Acres per County	Adjustment for Yard Waste Generated
< 10	Zero out
>=10 and <50	Multiply by 50%
>=50	Assume 100%

The final step is to account for burning bans in the same manner that was used for household waste.   Once the activity data is estimated, emissions are calculated by the use of Equation 9-1. A 100% CE is assumed for counties that have an urban population greater than 80% of the total population. The NEI also assumes that RE and RP are 100% for these areas. The NEI assumes that all other counties are uncontrolled.

Equation 9-1. Emission Estimation Formula for Household and Yard Waste Burning

$$E = A*EF*(1-CE*RP*RE)$$

where:
E = Controlled emissions (lbs pollutant/year)
A = Activity (tons of waste burned/year)
EF = Emission factor (lbs/ton waste burned)
CE = % Control efficiency/100
RP = % Rule penetration/100
RE = % Rule effectiveness/100

There is an EIIP document for open burning and it contains an alternative approach for estimating emissions for yard waste.   This approach involves obtaining records of burning permits or violations and data (or assumptions) on typical volumes and material composition.

9.2.1.2 Improving the NEI

The open burning EIIP (Volume III, Chapter 16) contains alternative methods for estimating activity data for this category.   Another approach is to use the NEI methodology coupled with state or local estimates of the per capita waste generation and the amount or percentage of waste burned. Also, state/local data on the months when yard waste is burned would be an improvement since the NEI does not make any temporal adjustment for yard waste burning.   Some of the sources for this type of information include the Solid Waste agency, the Air

Agency, the Health Department, the Solid Waste Management agency, and through the use of local surveys.

The NEI can also be improved by obtaining better estimates of control measures that are applied to open burning. This involves identifying the rules that limit or prohibit open burning and the organization that enforces those rules (e.g., fire marshal, health department). For areas that have burning prohibitions, a rule effectiveness survey can be performed to estimate the compliance rate with the rule. This is critical in rural areas where there are few complaints about open burning. Also, rule penetration is critical since many open burning rules have exemptions that are listed (e.g., firefighting training activities, recreational campfires). Rule penetration is also important for seasonal bans.

9.2.1.3 MANE-VU Example

This example examines the development of a 2002 residential open burning inventory for the MANE-VU states. This was developed by a multi-state Regional Planning Organization and followed the procedures in the EIIP document (i.e., conducting a survey) to obtain activity data.

A survey instrument was developed to collect data on the number of households that burn waste, the burn frequency, the amount burned, and the seasonal nature of the burning. Three separate surveys were performed for residential municipal solid waste, brush waste and leaf waste. The data collected from these surveys were used to estimate emissions for each survey area and to estimate default activity data for those areas not included in the surveyed areas.

Equation 9-2 shows the equation that was used to estimate the amount of waste burned based on the data collected from the surveys.

Equation 9-2. Equation for Estimating Mass of Waste Burned

$$Wt = HH * Bt * M$$

where: Wt = Mass of waste burned per time period
HH = Number of households that burn
Bt = Number of burns per time period
M = Mass of waste burned

In addition to collecting data to estimate activity data, a control database was developed that established area-specific control efficiency, rule effectiveness, and rule penetration. Because rule effectiveness and rule penetration can vary significantly depending on enforcement and the rule applicability, a rule effectiveness survey was conducted to determine the level of compliance with the state or local open burning prohibitions. This data was also used to estimate default RE values for use in the non-surveyed areas.

Using the activity data and the control information, emissions were estimated for all criteria pollutants and precursors as well as for several HAPs. The emissions were estimated at the census track level and then summed to the county, state, and regional level. Finally, the data on the occurrence of the burning activities were used to temporally allocate the emissions to support modeling using profiles that were developed from the survey.

A number of lessons were learned from conducting the survey including that separate surveys should be performed in targeted areas where leaf burning is significant. In addition, household waste and yard waste surveys should be performed separately simply to reduce the length of the survey. Another lesson learned is that a larger sample may have allowed for greater geographic distinction. In addition, a regional survey provides greater consistency that allows for easier comparison of emission estimates from different areas. Finally, better accounting of controls results in a decrease of the NEI emissions.

9.2.2 Land Clearing Debris Burning

Land clearing debris burning is covered under SCC 2610000500. The NEI contains emission estimates for PM_{10}, $PM_{2.5}$, CO, VOC, and 6 HAPs from this category.

9.2.2.1 NEI

The activity data for this category is the same as that used for the construction category (i.e., the number of acres disturbed for the different types of construction categories). A loading factor is applied to the number of acres disturbed to produce an estimate of the amount of material that is being burned. Weighted county-specific loading factors were developed based on the acres of hardwood, softwoods, and grasses. The average loading factors (Table 9-10) are multiplied by the percent contribution of each type of vegetation class to the total county land area. The average loading factors for hardwood and softwoods were adjusted by an additional 1.5 to account for the mass of tree below the surface. It should be noted that the emission factors presented in Table 9-10 reflect this adjustment.

Table 9-10 Fuel Loading Factors

Fuel Type	Fuel Loading (tons/acre)
Hardwood	99
Softwood	57
Grass	4.5

Equation 9-3 shows the formula for developing the loading factors.

Equation 9-3. Equation for Estimating Fuel Loading Factor

$$L_w = F_h*L_h + F_s*L_s + F_g*L_g$$

where: L_w = County-specific weighted loading factor
F_h = Fraction of county acres classified as hardwoods

L_h = Average loading factor for hardwoods
F_s = Fraction of county acres classified as softwoods
L_s = Average loading factor for softwoods
F_g = Fraction of county acres classified as grasses
L_g = Average loading factor for grasses

Emissions are estimated from the activity data as shown by Equation 9-4. This formula multiplies the activity data, the number of acres of land, and the county-specific loading factor. Since the loading factor does not vary by the types of construction, the number of acres cleared for all three types of activities (residential, commercial, and road construction) are summed before the loading factor is applied. The NEI assumes that all the fuel loading on the land cleared is burned and that no controls or bans are in place.

Equation 9-4. Equation for Estimating Emissions from Land Clearing Debris Burning

$$E = A * LF * EF$$

where: E = Emissions (lbs pollutant/year)
A = Number of acres cleared per county
LF = County-specific loading factor (tons/acre)
EF = Emission factor (lbs pollutant/ton)

9.2.2.2 Improving the NEI

The NEI does not take into account data on burning practices or controls, so a good place to begin to improve the NEI is to review the EIIP section on open burning. The EIIP methods rely on a direct measure of mass of waste or debris burned, which may be obtainable from local officials that track this activity for permitting purposes. Also, obtaining a better estimate of the acres cleared for the fugitive dust construction category would improve the inventory for the land clearing debris burning category. Other approaches for improving the NEI include:

- Developing an improved loading factor.
- Identifying specific counties with burning bans.
- Specifying counties where wastes are burned.
- Obtaining state or local estimates of the percentage or amount of waste burned per construction event (the NEI assumes that the fuel loading associated with the land that is cleared is being burned).

9.2.2.3 Northern Virginia Example

This Northern Virginia area study involved a RE survey to determine the level of compliance with rules for land clearing debris burning and residential waste burning. The objective of the study was to develop a defensible RE value for use in the State Implementation Plan.

The study reviewed the existing conditions of the open burning rules to determine the time period of the ban and the exemptions that apply. A survey of local open burning officials responsible for tracking and enforcing open burning rules was conducted. The survey form was derived from an EPA questionnaire that is available from the rule effectiveness guidance. Responses to the questions on the survey were assigned a specific point value that adds up to a maximum of 100 points. This point value is considered equivalent to the RE percentage value. If all the questions were answered with the highest rating, an RE value of 100% was assigned. The RE values were analyzed by county as well as for the five-county region and a regional RE value of 93% was estimated. Although not done in this case study, separate RE values could be developed for urban and rural area in cases where there are significantly different population densities.

Some of the lessons learned from this study are that the local officials tend to defer to the county or state level officials for enforcing the open burning rules. Also, in developing an annual emissions inventory, it is important to note that RE may be high only for the time period that the ban is in effect. In this case, the duration of the ban (RP) needs to be taken into account if it is less than annual or seasonal. Also it is important to account for when the ban is taking place and if it overlaps with when the activity occurs. For example, a ban in place for the summer months for brush waste burning will have minimal impact if the majority of the brush burning occurs in the fall.

9.3 Agricultural Field Burning

9.3.1 Introduction

Agricultural burns create particulate matter pollution and their inventory is important to the overall particulate matter air quality analysis. The SCC for agricultural burning is 2801500000 and EPA encourages States to inventory both PM10 and PM2.5-PRI. Since agricultural burning is a combustion process, both condensibles and filterables are included in the PM-PRI estimate.

EPA develops emission estimates for most source categories in the NEI and then the States submit any improved information that they have for those particular categories. However, for agricultural burning EPA does not at this time prepare an estimate of emissions from agricultural burning. In this case EPA encourages each State to develop their own inventories and submit them. In 1999 ten States (Alabama, California, Delaware, Georgia, Idaho, Kansas, Maine, Oregon, Texas, and Utah) developed their own agricultural burning inventory. In general, these States developed the inventories by characterizing the activity or acres of the crop burned, the loading factor, the ton of biomass of vegetation per acre burned, and the emission factor in terms of pounds of $PM_{2.5}$ per ton.

9.3.2 Wheat Stubble Burning Example

This study involves wheat stubble burning and uses county-specific data. The activity data that was obtained are the acres of wheat burned by month. This was obtained from burn permits that are usually issued by the county fire department.

Also, the fuel loading for wheat stubble was obtained from the county agricultural extension office. The emission factors are from a study done by CARB (Jenkins, B.M. et al., *Atmospheric Pollutant Emission Factors from Open Burning of Agricultural and Forest Biomass by Wind Tunnel Simulations*, Volume 2, Results, Cereal Crop Residues, California Air Resources Board Project Number A932-126). The emission factors are 8.82 pounds per tons of wheat stubble burned for PM_{10} and 8.34 for $PM_{2.5}$. The spatial resolution for this inventory is the county and the temporal resolution is monthly. Equation 9-5 shows the formula for calculating PM2.5-PRI emissions. This calculation would be repeated for each month during the burning season and summed to give an annual emissions estimate. It should be noted that if the number of acres burned per fire is larger than 100 acres; the specific latitude and longitude of the fire should also be obtained.

Equation 9-5. Equation for Estimating Emissions from Agricultural Burning

$$E = A * LF * EF$$

where: E = Emissions (lbs pollutant/month)
A = Number of acres burned per month
LF = Loading factor (tons/acre)
EF = Emission factor (lbs pollutant/ton)

9.3.3 Improvements

EPA encourages all states to develop their own agricultural burning inventory. For fires larger than 100 acres EPA suggests that they be located at a specific latitude and longitude and the stop and start date and time of the fire be recorded. Smaller fires should be lumped into overall monthly acreage like in the previous case study example. Obtaining information on agricultural burning requires coordination with the burners and the permitting authorities. In order to develop an agricultural burning inventory, states needs to build a system and a relationship with the burners and permitting authorities. Chances are pretty good that the first time a State tries to obtain this information they will find that records are not kept or are not kept in a way that can easily be understood.

The local acres of crops burned are obtained from burn permits or from a survey of county agricultural extension offices or perhaps a combination of both. It is important that States verify that the burns actually occurred. Often a burner will get a permit to burn a lot more acreage than they actually are able to burn in a particular day. In many cases a burner is limited by the weather or other factors that keep them from burning the acreage that they are permitted to burn. Finally, States need to obtain local fuel loading data. This is preferably obtained from the local county agricultural extension office or the local Natural Resources Conservation Service Center. This is highly preferable to using the national defaults that are available in Chapter 2.5 of AP-42.

9.4 Wildland Fires

Fires have become a major issue in both visibility impairment and in creating high concentrations of $PM_{2.5}$ that could result in health problems. The problems have been mainly in the West, but also wildfires from the Southeast, the Central States, Canada, and Mexico have become a concern. EPA's wildland burning inventory includes both wild and managed burns. The typical agencies that burn are the National Park Service, the United States Forest Service, the Bureau of Land Management, the United States Fish and Wildlife Service, State & Tribal Forests, and private burners. Wildland fires are categorized into two types: wildfires and managed or prescribed burns. Prescribed burns are those burns that are ignited intentionally for habitat improvement of the wildlife; for managing the overall under growth and understoring of the forest; and to reduce the risk of wildfires later on by removing the fuels from the forested area.

9.4.1 NEI

It should be noted that this discussion focuses on the technique for estimating emissions from wildfires; however, emissions from prescribed or managed fires are estimated in a similar fashion. The pollutants that are included in the NEI inventory for wildland fire emissions are PM_{10}, $PM_{2.5}$, NOx, CO, VOC, SO_2, and about 30 HAPS. The emissions factors for estimating fire emissions, and the state-specific fuel consumed per acre burned are found in the NEI documentation. The technique is to merge the factor and fuel consumption information with annual activity data obtained at either the state or regional level from the main burning agencies. Most of the federal burners keep fairly good records of the burns that they conduct mostly because these fires end up being watched and/or fought by personnel. Some states also provide burn data as do some private burners.

The data obtained from the burners is at the state level or regional level and it is allocated to the state or county level using the amount of forested area in a state. In other words, since the NEI does not have data on the exact location of the fires, the amount of acreage that was burned during a year in a particular state is allocated across the state to the forested lands.

The NEI allocates the emissions annually and the emissions processor allocates the emissions diurnally and monthly. This allocation is important because certain areas of the country have different fire seasons and fire seasons are different for prescribed burns and managed burns.

9.4.2 Improving the NEI

In order to improve wild land fire emissions, national and regional databases and models must be improved. Fires need to be treated as events (i.e., specify the area burned, when it was burned, and where it occurred). In addition, large fires need to be entered into the databases as point sources with a particular location (lat/long) and a start date, end date, and the time of day.   National regional models and databases need to be developed and refined to improve the pre-burn fuel loading information. The information in AP-42 is very general, very dated, and averaged over large regions of the country. Finally, the use of fuel consumption models needs to be to refined and expanded and guidance on estimating the impact of mitigation measures on emissions needs to be provided.

There is a Memorandum of Understanding (MOU) in effect between the EPA, Department of Interior, and the United States Department of Agriculture to develop a fire events database. It is a broad scope MOU that covers fire management activities including ways to improve the national databases. There is a similar effort (NEISGEI) being conducted at Washington University in St. Louis. There currently exists a database for recording fire events in the Pacific NW called the B-RAINS system. Although these types of projects are moving toward real time data collection, quality assurance and data sharing, there is much more work needed in these areas.

EPA is also investigating the potential use of satellites to improve wildland fire inventories. EPA has funded a report entitled *Overview of Using Satellites in AQ Management*. There is also collaboration going on with NASA to take advantage of their skills in aerial surveillance with satellites. There are several interagency groups working on the use of satellites including the National Interagency Fire Center (a jointly funded effort of all the Federal burners) in Boise, Idaho, the Missoula Fire Research Center, and Salt Lake City. Another project includes CAMFER, which is a project underway at University of California Berkeley.

9.4.3 Emission Estimation Tools and Inventories

EPA recently published a report entitled *Fire Emission Estimation Methods* (available on the CHIEF web site) that contains a lot of good background information on wildland fire emission estimation. In addition, there is a lot of ongoing work to improve emission estimation tools for wildland fires. The US Forest Service has ongoing work on the development of fuel consumption and fire behavior models at the Fire Sciences Lab in Missoula and also at the Pacific NW Research Station in Corvallis. Also, there is also a lot of emission factor testing occurring in the Fire Sciences Lab in Missoula.

There is also collaboration going on between all the different burn agencies, EPA, and the Regional Planning Organizations (RPO). The Western Regional Air Partnership (WRAP) conducts a fire emissions joint forum and EPA and the burn agencies participate in that forum. There is a RPO project to refine the 2002 wildland fire emissions inventory. There was a national fire emissions workshop held in May of 2004 that focused on the latest ideas and methodologies for estimating fire emissions. Also, the US Forest Service with assistance and funding from EPA is developing a geographic coverage of the fuel types and fuel conditions for burning at a 1km resolution. A map of the country that will be useful in GIS systems will be developed out of this project. Finally there will be further work on developing an emissions model that will estimate fire emissions in real time using real time meteorological data. Output from this model will be fed directly into the grid models for estimating ambient air concentrations associated with fire emissions.

The emissions model that is under development is the Wildlands Fire Emissions Model. It will interface with SMOKE and OpEMs (the emissions model that is under development by the RPO), and the CMAQ modeling system. The user will need to input fire locations, durations, and size of the fire (i.e., the blackened area of the fire). The model components, which will be drawn from the Blue Sky system being developed in the Pacific NW, are:

1. A fuel loading default that will use either the national fire danger rating system or, as it becomes available, the FCC map.
2. Fuel moisture will be calculated using actual metrological data for the period during, and immediately before the fire. This is a significant improvement over the past and an important improvement since fuel moisture is critical in determining the amount of fuel that will burn and the emissions from that fuel.
3. Fuel consumption models are being built into the model. Both the CONSUME / FOFEM are such models that have recently been improved significantly. The CONSUME model is developed in the Corvallis lab and the FOFEM has been developed by the Missoula Fire Lab. These models compliment each other and have strengths and weakness that, when used together properly, give a pretty good handle on fuel consumption.
4. The emission heat release and plume rise is being handled through the EPM model and the modified Briggs plume rise equation. There is an improvement to the EPM model called FAR, which is about to be released in beta test form.

The output of the model will be a gridded hourly emission estimate and plume characteristics. The output will be able to be interfaced with grid models to provide a regional scale estimate of the effects of fires. For instance, this new wildland fire model will be able to estimate the NOx plume from a wildland fire and the effects of that increased NOx on ozone formation. The integration, testing, and release of the model are anticipated for late 2004.

Review Exercises

1. The NEI methodology for residential wood combustion made adjustments to the national number of fireplaces to account for _______.
   a. fireplaces that burn gas
   b. fireplaces without inserts
   c. fireplaces used for aesthetic purposes
   d. All of the above

2. Which type of residential wood combustion is not allocated to different SCCs?
   a. woodstoves
   b. fireplaces with inserts
   c. fireplaces without inserts
   d. All of the above

3. The NEI methodology for residential municipal solid waste burning assumes that if a county has an urban population that exceeds _______ percent of the total population, the amount of waste burned is zero.
   a. 50
   b. 75
   c. 80
   d. 90

4. The NEI methodology for residential municipal solid waste burning assumes that _______ percent of household waste generated is burned.
   a. 18
   b. 28
   c. 38
   d. 48

5. The land clearing debris burning load factors for _______ are adjusted by an additional 1.5 to account for the mass below the surface.
   a. hardwoods and grasses
   b. softwoods and grasses
   c. hardwoods and softwoods
   d. All of the above

6. The activity data for land clearing debris burning is the same that is used for the _______ category.
   a. agricultural burning
   b. unpaved roads
   c. agricultural tilling
   d. construction

7. Which of the following variables are not used in the NEI to estimate emissions from land clearing debris burning?
   a. number of acres cleared
   b. county-specific loading factor
   c. emission factor
   d. rule effectiveness

8. For which of the following categories did the NEI not develop a methodology?
   a. agricultural field burning
   b. agricultural tilling
   c. wood stoves
   d. land clearing debris burning

9. Which of the following is **not** a source of variability in wood consumption activity in the MANE-VU study?
   a. type of housing
   b. heating degree days
   c. moisture content of wood
   d. availability of wood

10. In estimating emissions from wildland fires, the data obtained from the burners is allocated to the state or county level using ______.
    a. the number of burn permits issued
    b. the number of acres burned
    c. the amount of forested land in a state
    d. All of the above

Review Answers

1. d. All of the above

2. c. fireplaces without inserts

3. c. 80

4. b. 28

5. c. hardwoods and softwoods

6. d. construction

7. d. rule effectiveness

8. a. agricultural field burning

9. c. moisture content of wood

10. c. the amount of forested land in a state

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